

IBM Corporation, T.J. Watson Research Center

## Jitney: A Low-Cost, High-Performance Optical Bus

*In the early 1990s, microcomputers were increasingly integrated into clusters and used as building blocks in distributed processing networks for different types of computing tasks. These tasks included “supercomputing,” which involved using several high-performance computers to work as a single system. In order for the clustering to be effective, the central processing units (CPUs) had to be connected through a high-speed data bus network, which consisted of the connections between and within the CPU, memory, and peripherals. At the time, data buses typically used copper wire, which was bulky and prone to interference; moreover, copper wire faced technical challenges when connection distances and data rates increased. One solution was to replace the copper wire with optical fiber, which was generally smaller, immune to electromagnetic interference, and able to carry more information faster. However, optical fiber was also more costly than copper wire.*

*In 1993, IBM Corporation, 3M Company, and Lexmark International, Inc. joined together and proposed to develop a much lower cost optical bus technology. The three companies formed the Jitney Joint Venture in an effort to combine electro-optical components and processes. The IBM-led joint venture was awarded cost-shared funding in 1994 from the Advanced Technology Program (ATP) for a two-and-a-half-year project. By the end of the project, the team had successfully developed and demonstrated a low-cost fiber optic bus. However, because of improvements in copper technology, new competing optical interconnect products, and concerns about meeting industry standards of interoperability between public and private networks, the group did not commercialize the technology. IBM has been able to apply the learning obtained from the Jitney project to develop sophisticated models of multimode fiber transmission and transceiver operation which are enabling very high speed computer links to be correctly designed.*

### COMPOSITE PERFORMANCE SCORE

(based on a four star rating)

★

Research and data for Status Report 93-01-0151 were collected during May – August 2004.

### Optical Buses Are Superior to Copper Data Buses

In the early 1990s, microprocessors and semiconductor memory were rapidly advancing in power and performance while, at the same time, decreasing in cost. As a result, microprocessors and semiconductor memory were widely used in personal computers and workstations to increase data processing performance. By 1993, there was a strong trend to integrate many microcomputers (consisting of clusters of processor/memory blocks) to create parallel and distributed processor systems. These parallel or distributed systems divide a program into multiple

segments that can be executed simultaneously on separate processors to speed the execution of the program. Microcomputers were becoming the “building block” for many types of computing systems, including “supercomputing,” where several high-performance computers are networked to perform as a single system. To integrate a group of microcomputers, one needed an interference-free high-speed data bus network to interconnect the processors. At the time, information was transmitted in a data bus with copper wire, which although cost effective, was bulky and prone to interference. As distances grew longer and data storage rates increased with the new computing

systems, it became more difficult to obtain satisfactory performance from copper data buses. In addition, the price of copper was rising.

---

*Information was transmitted in a data bus with copper wire, which although cost effective, was bulky and prone to interference.*

---

Using optical buses was seen as a potential solution. Fiber optic technology transmits light through long, thin, flexible fibers of glass, plastic, or other transparent materials. The technology had already been developed for long-distance telecommunications between transmitters and receivers and for highly multiplexed traffic that involved many simultaneous conversations. In the area of telecommunications, it had demonstrated superior performance over the more traditional copper-based interconnect systems. Optical fibers were generally smaller, more resistant to electromagnetic interference, and able to carry more information in less time than copper wire. However, components made from optical fibers were also more expensive to manufacture, install, and maintain than those made with copper wire.

#### **Jitney Joint Venture Proposes to Develop a Low-Cost Optical Bus**

In 1993, three organizations came together and formed a consortium (the Jitney Joint Venture) to develop a solution to the data bus problem. IBM Corporation was a leading designer and manufacturer of commercial computer systems; 3M Company was a leading supplier of single-mode and multimode fiber optic components for telecommunications, private network, and avionics/military applications; and Lexmark International, Inc. was a designer, developer, and original equipment manufacturer of products for the computer industry. The three-member consortium believed that by developing and modifying some of the existing optical and electro-optical devices, it could create a low-cost optical data bus (or Jitney) that could be used to link clusters of microcomputers in advanced applications. IBM already had developed several components such as integrated photo receiver chips and lead frames, as well as processes that could be used for the new technology.

#### **Venture Participants Anticipate Broad-Based Benefits**

The joint venture believed that developing a much lower cost optical bus technology would result in significant broad-based benefits for the U.S. economy. It was estimated that the market for the initial microcomputer cluster applications would grow to more than \$500 million by 1997. Markets in data communications and interconnects were expected to total more than \$2 billion by the late 1990s.

Furthermore, an opto-electronic technology infrastructure for producing low-cost modules, cables, and connectors would be established. This infrastructure could be used to produce components for many applications, such as the following:

- Single-line connections used in industrial and business local area networks or in the home for entertainment, environmental control, and security.
- Single and multiple-fiber sensor systems for military and aerospace applications, as well as industrial automation and automotive applications. The consortium anticipated that the potential annual earnings in these markets would be millions of dollars.
- Medical imaging systems, such as computed x-ray tomography (procedure that produces an image [tomogram] of a selected layer of tissue) and magnetic resonance imaging. In these systems, large amounts of data could be moved at a high speed between sensing, processing, imaging, and printing equipment.
- Medical procedures and equipment, such as laser surgery and blood gas sensors. The large-core fibers would be able to handle the transfer of large amounts of power during these procedures. Also, the low cost of the components would make it possible for them to be replaced after each use, reducing the risk of spreading infection.

In addition, U.S. proficiency in the field of opto-electronic technology would increase, making the United States more competitive with Japan, the global leader at the time.

## **Development of Low-Cost, Optical Data Bus Poses High Risk**

The team understood that developing a low-cost, high-performance optical bus was a high-risk endeavor. The high-performance optical bus would have to eliminate the precise, labor-intensive, time-consuming, and expensive processes normally associated with applying a connector to a ribbon cable (ribbon cables are common connectors for internal peripherals such as CD-ROM drives and hard disk drives). The approach would consist of assembling connector parts into the cable while the cable is being manufactured. To do this, the joint venture would have to make the correct trade-offs in component specifications and overall bus performance; would have to control component design, tooling, and assembly costs; and would have to simplify the assembly and testing processes.

Because the project risks were more than each of the companies could assume at the time, the consortium sought financial support from ATP. This support would allow the companies to develop a low-cost optical bus technology and accelerate the research and development for the technology by two years. Furthermore, ATP funding would provide a stable environment and structure for interactions between the three companies. The funding would also promote a free flow of ideas between engineers from different companies with different skills and backgrounds.

### **Joint Venture Team Establishes Technical Objectives**

The team established the following technical objectives:

- Develop transmitter and receiver modules and a parallel fiber cable for the optical bus technology that would be cost competitive with copper wire interconnects
- Test the optical bus in a computer subsystem
- Assess whether the new technology could be manufactured at a low cost and compare its performance and features with copper bus technology

To lower the cost of the optical bus technology, the participants would assess the materials, labor, and

degree of process control necessary to manufacture a component. An important strategy for lowering the cost of manufacturing the cable assembly and modules would be to use large-core, step-index optical fiber. This fiber, which is 200  $\mu\text{m}$  in diameter, would allow for the relaxation, or reduction, in the mechanical alignment tolerances necessary for efficient optical coupling (the joining of two circuits through a light beam or light pipe with transducers at opposite ends in order to isolate the circuits electrically). The main challenge, however, in using large-core, step-index optical fiber would be to maintain sufficient distance capability (500 Mb/sec/channel) for data, because of bandwidth degradation as the distance between receivers increased.

### **Consortium Successfully Develops a Low-Cost Fiber Optic Bus**

During the ATP-funded project, the consortium made several changes to its development plan based on requests for greater optical link performance from potential users and the discovery of new ways to lower the cost of the optical bus. These changes included the following:

- Changing from light-emitting diode (LED) array chips to VCSEL (Vertical-Cavity Surface-Emitting Laser, which is a semiconductor laser with perpendicular laser beam emissions, contrary to conventional edge-emitting semiconductor lasers) array chips. While an LED is the simplest device used for optical transmission (a process during which the semiconductor diodes emit light when charged with electricity), the VCSEL array chip was a less expensive, faster, and more efficient device than the LED.
- Expanding the optical coupler into a two-part component to reduce the cost of molding and to increase yield. To accomplish this, the participants collaborated with Pitney Bowes and Apex Machine Tool Co. to fabricate a lens array mold that could be used.
- Developing a graded-index fiber ribbon cable that could be retrofitted to the original step-index optical fiber ribbon to create links longer than the 30 meters that was the consortium's original goal. This would provide users with low-cost step-index fiber

for at least 75 percent of their links and the option of using the more expensive graded-index fiber when it was needed.

By the end of the ATP-funded project, the team had met its technical objectives, including the following:

- Designed and fabricated opto-electronic and integrated circuit chips.
- Fabricated two types of optical couplers, one of which exceeded the performance objectives.
- Designed and fabricated a plastic lead frame package, assembled chips and optics in the package, and demonstrated that the package could meet cost and performance objectives.
- Fabricated two types of cable, each with a different type of fiber, in a 20-line fiber ribbon (for this, the team used an innovative assembly technique developed during the project).
- Demonstrated high bandwidth over relaxed tolerances.
- Developed both module and in-line cable connectors.
- Characterized the cables and modules individually and in pairs and inserted them into two test beds (the main test bed consisted of a group of IBM AS/400 prototype computers in which interprocessor benchmark jobs were performed over Jitney fiber links). The multiprocessor benchmark was also successfully demonstrated.
- The resulting Jitney Parallel Optical Interconnect consisted of a transmitter module, a receiver module, and a cable capable of sending 1 GB/sec over 1- to 100-meter spans.

The Jitney project also resulted in four patents and over 25 publications and presentations.

### **Commercialization Plans Developed, But Not Implemented**

In 1996, approximately one year before the ATP-funded project ended, the joint venture began plans for commercializing the fiber optic technology. It assessed the most promising market segments (telecommunications, data processing, data networking,

and military/aerospace) and conducted interviews with potential customers. At the same time, however, there was a growing concern within the marketing group that, even though the technology had been successfully demonstrated and potential customers had been identified and were enthusiastic about it, the technology would not conform to the industry's technical standards of interoperability between private and public networks.

---

*The three-member consortium believed that it could create a low-cost optical data bus (or Jitney) that could be used to link clusters of microcomputers in advanced applications.*

---

By the end of the ATP-funded project in 1997, a number of changes had also occurred in the parallel optical interconnect environment. These changes included a growing demand for greater bandwidth, new improvements that had been made in copper technology, and new competing optical interconnect products that had entered the marketplace from companies such as Motorola, Hewlett Packard, and Siemens. Consequently, the team did not commercialize the Jitney technology. Since the ATP-funded project ended, IBM has been able to apply the research from the Jitney project to develop models of multimode fiber transmission and transceiver operation which were later developed and verified under the ATP Photonics Computer-Aided Design (PCAD) project, which are enabling very high speed electro-optical computer links to be correctly designed.

### **Conclusion**

With ATP's assistance, the Jitney Joint Venture (IBM Corporation, 3M Company, and Lexmark International, Inc.) successfully developed an optical data bus that was cost competitive with the copper data bus. The team accomplished this by modifying and developing optical and electro-optical devices (such as photo receiver chips and lead frames) and processes that had previously been developed by IBM. Moreover, the joint venture participants met specified price targets for cables, connectors, and modules and correctly assessed the materials, labor, and process control for the component.

However, by the end of the ATP-funded project in 1997, they did not successfully commercialize the optical data bus. The Jitney team had a growing concern that the optical data bus would not conform to industry standards of interoperability between private and public networks; processors were operating at higher speeds; and more multiprocessor systems had become available, resulting in a growing demand for greater bandwidth. Furthermore, improvements had been made to copper technology, and new competitors, such as Motorola and Hewlett Packard, had entered the optical interconnect market.

Since the project ended, IBM has used elements of the ATP-funded technology, such as circuit designs, to develop new chips. It has also used the learning from the ATP-funded research to develop multimode fiber transmission and transceiver operation, later developed under the NIST/ATP Photonics Computer-Aided Design project, which are enabling very high speed electro-optical computer links to be correctly designed. The Jitney project resulted in numerous patents, publications, and presentations.

## PROJECT HIGHLIGHTS

### IBM Corporation, T.J. Watson Research Center

**Project Title:** Jitney: A Low-Cost, High-Performance Optical Bus

**Project:** To develop and modify existing volume-produced optical and electro-optical devices to create a low-cost optical data bus for linking clusters of microcomputers in advanced applications.

**Duration:** 9/13/1994 - 3/31/1997

**ATP Number:** 93-01-0151

#### Funding\*\* (in thousands):

ATP Final Cost	\$3,073	45%
Participant Final Cost	<u>3,685</u>	55%
Total	\$6,758	

**Accomplishments:** With ATP funding, the Jitney Joint Venture (IBM Corporation, 3M Company, and Lexmark International, Inc.) accomplished the following:

- Developed a low-cost optical data bus by designing and modifying existing volume-produced optical and electro-optical devices.
- Disseminated knowledge gained during the project through many publications and presentations (see end of this report).

The Jitney Joint Venture also received the following patents for technologies related to the ATP-funded project:

- "Method for extending bandwidth of large core fiber optic transmission links"  
(No. 5,495,545: filed October 24, 1994; granted February 27, 1996)
- "Low-cost packaging for parallel optical computer link"  
(No. 5,781,682: filed February 1, 1996; granted July 14, 1998)
- "Optical coupler"  
(No. 6,075,913: filed February 27, 1998; granted June 13, 2000)
- "Lead frame and lead frame assembly for parallel optical computer link"  
(No. 6,137,158: filed June 1, 1998; granted October 24, 2000)

**Commercialization Status:** The Jitney Joint Venture did not commercialize the low-cost optical bus that it developed in the ATP-funded project.

**Outlook:** The outlook for this project is poor since the low-cost optical bus was not commercialized. But IBM has been able to apply elements of the technology to the development of new chips. IBM has also used it to develop a Photonic Computer-Aided Design (PCAD) technology that may be capable of transmitting data more rapidly than the low-cost optical bus.

#### Composite Performance Score: \*

#### Company:

IBM Corporation  
Route 134, Kitchawan Road  
Taconic Parkway  
Yorktown Heights, NY 10598-0210

**Contact:** Dr. Marc Taubenblatt

**Phone:** (914) 945-1322

#### Publications:

- Crow, J.D. "Jitney and OETC Parallel Optical Links." 1995.
- Choi, J., D.L. Rogers, D.M. Kuchta, Y.H. Kwark, H. Ainspan, K.G. Stawiasz, and J.D. Crow. "High Performance, High Yield, Uniform 32 Channel Optical Receiver Array." *Conference on Optical Fiber Communication (OFC '96), Optical Society of America*, pp. 309-310, February–March 1996.
- Crow, J.D. "The Jitney Parallel Optical Interconnect." April 1996.
- Crow, J., N. Lee, et al. "The Jitney Optical Interconnect" *Proceedings of the 46th Electronic Components and Technology Conference*, pp. 292-300, May 1996.
- Crow, J.D. "Jitney Low Cost Optical Bus." June 1996.
- Crow, J.D. "Data Processing and Data Communications Network – The Drive for Cost Effective Technology." September 1996.

\*\* As of December 9, 1997, large single applicant firms are required to pay 60% of all ATP project costs. Prior to this date, single applicant firms, regardless of size, were required to pay indirect costs.

## PROJECT HIGHLIGHTS

### IBM Corporation, T.J. Watson Research Center

- Crow, J.D. "Parallel Fiber Optical Bus Technology – A Cost Performance Breakthrough." 22nd European Conference on Optical Communication (ECOC '96), Telenor R&D, pp. 47-54, September 1996.
- Crow, J.D. "Parallel Optical Interconnect – A Cost Performance Breakthrough." 9th Annual Lasers and Electro-Optics Society Annual Meeting (LEOS '96), IEEE, 3-4, November 1996.
- DeBaun, B., et al. "Direct VCSEL Launch Into Large Core Multimode Fibers: Enhancement of the Bandwidth x Distance Product." *Proceedings of the International Society for Optical Engineering (SPIE)*, p. 142, 1997.
- Stawiasz, K., et al. "Automated Testing Methodologies for Low Cost, Parallel Optical Bus Components." *Proceedings of 47th Electronic Components and Technology Conference, IEEE*, p. 217, 1997.
- Lee, N., et al. "Automated Method for Fabrication of Parallel Multifiber Cable Assemblies with Integral Connector Components." *SPIE Proceedings*, Vol. 3005, pp. 58-64, February 1997.
- Igl, S., N. Lee, et al. "Automated Assembly of Parallel Fiber Optic Cables." *Proceedings of the 47th Electronic Components and Technology Conference*, pp. 404-409, May 1997.
- Johnson, G., N. Lee, et al. "Relaxed Tolerance, Plastic Components for use in Low Cost Gigabyte/Sec Parallel Optical Data Interconnect." *Proceedings of 1997 Plastic Optical Fiber Conference*, September 1997.
- Crow, J., N. Lee, et al. "Jitney Gigabyte/sec Optical Bus (Fiber Optics Designed for Low Cost)." *Proceedings of Optical Society of America (OSA) Annual Meeting*, October 1997.
- Cohen, M.S., et al. "Packaging Aspects of the Jitney Parallel Optical Interconnect." *Proceedings of 48th Electronic Components and Technology Conference, IEEE*, pp. 1206-1215, 1998.

### Presentations:

- Choi, J., D.L. Rogers, D.M. Kuchta, Y.H. Kwark, H. Ainspan, K.G. Stawiasz, and J.D. Crow. "High Performance, High Yield, Uniform 32 Channel Optical Receiver Array." Conference on Optical Fiber Communication (OFC '96), San Jose, CA, 1996.
- Crow, J.D. "The Jitney Parallel Optical Interconnect." April 1996.
- Crow, J., J. Choi, M. Cohen, and G. Johnson. "The Jitney Parallel Optical Interconnect." The 46th Electronic Components and Technology Conference, Orlando, FL, May 1996.
- Crow, J.D. "Jitney Low Cost Optical Bus." June 1996.
- Crow, J.D. "Parallel Fiber Optical Bus Technology – A Cost Performance Breakthrough." 22nd European Conference on Optical Communication (ECOC '96), Oslo, Norway, September 1996.
- Crow, J.D. "Data Processing and Data Communications Network – The Drive for Cost Effective Technology." September 1996.
- Crow, J.D. "Parallel Optical Interconnect – A Cost Performance Breakthrough." 9th Annual Lasers and Electro-Optics Society Annual Meeting, Boston, MA, November 1996.
- Stawiasz, K., et al. "Automated Testing Methodologies for Low Cost, Parallel Optical Bus Components." 47th Electronic Components and Technology Conference, San Jose, CA, 1997.
- DeBaun, B.A., et al. "Direct VCSEL Launch Into Large Core Multimode Fibers: Enhancement of the Bandwidth x Distance Product." SPIE – The International Society for Optical Engineering, February 1997.
- Lee, N., et al. "Automated Method for Fabrication of Parallel Multifiber Cable Assemblies with Integral Connector Components." SPIE Conference, San Jose, CA, February 1997.

## **PROJECT HIGHLIGHTS**

### **IBM Corporation, T.J. Watson Research Center**

- Lee, N., et al. "Automated Assembly of Parallel Fiber Optic Cables." 47th Electronic Components and Technology Conference, San Jose, CA, May 1997.
- Johnson, G.W., J. Crow, et al. "Relaxed Tolerance, Plastic Components for Use in Low Cost Gigabyte/Sec Parallel Optical Data Interconnects." Plastic Optical Fiber Consortium, Kauai, HI, September 1997.
- Crow, J., N. Lee, et al. "Jitney Gigabyte/sec Optical Bus (Fiber Optics Designed for Low Cost)." Optical Society of America (OSA) Annual Meeting, Long Beach, CA, October 1997.
- Cohen, M.S., et al. "Packaging Aspects of the Jitney Parallel Optical Interconnect." 48th Electronic Components and Technology Conference, Seattle, WA, 1998.